ILRS SLR MISSION SUPPORT REQUEST FORM (June 2011)

SECTION I: MISSION INFORMATION:

General Information:

Satellite Name: SpinSat

Satellite Host Organization: Naval Research Laboratory

Web Address:

Contact Information:

Primary Technical Contact Information:

Name: Andrew Nicholas

Address: 4555 Overlook Ave

Washington, DC 20375

Phone No.: 202-767-2441

Fax No.:

E-mail Address: andrew.nicholas@nrl.navy.mil

Alternate Technical Contact Information:

Name: Jake Griffiths

Address: 4555 Overlook Ave

Washington, DC 20375

Phone No.: 202-404-3508

Fax No.:

E-mail Address: jake.griffiths@nrl.navy.mil

Primary Science Contact Information:

Name: Andrew Nicholas

Address: 4555 Overlook Ave

Washington, DC 20375

Phone No.: 202-767-2441

Fax No.:

E-mail Address: andrew.nicholas@nrl.navy.mil

Alternate Science Contact Information:

Name: Linda Thomas

Address: 4555 Overlook Ave
Washington, DC 20375

Phone No.: 202-404-2062

Fax No.:

E-mail Address: linda.thomas@nrl.navy.mil

Mission Specifics:

Scientific or Engineering Objectives of Mission:

1. To characterize the performance of new electrically controlled solid propellant thrusters.
2. To provide total atmospheric density along the orbit track.
3. Calibration object for space object characterization sensors.

Satellite Laser Ranging (SLR) Role of Mission:

1. Provide high fidelity ranging observations for use in determining precision orbit solutions
2. Provide ground measurements of spacecraft spin rates to characterize performance of thrusters.

Anticipated Launch Date: September 19, 2014 Launch (deploy 1-2 weeks later)

Expected Mission Duration: 1 yr

Orbital Accuracy Required:

Anticipated Orbital Parameters:

Altitude: 425 km

Inclination: 51.6 deg

Eccentricity: 0.0

Orbital Period: 93 min

Frequency of Orbital Maneuvers: 2-3/week for first 3 mos. (spin increases/decreases)

Mission Timeline: Sept 2014 to Sept 2015

Tracking Requirements:

Tracking Schedule: Campaign style, Full passes requested (horizon-to-horizon), back-to-back passes desired

Spatial Coverage: no spatial preference

Temporal Coverage: Full duration passes (7-10 min)

Operations Requirements:

Prediction Center: Naval Research Laboratory

Prediction Technical Contact Information:

Name: Jake Griffiths

Address: 4555 Overlook Ave, SW, Code 8123

Washington, DC 20375

Phone No.: 202-404-3508

Fax No.:

E-mail Address: jake.griffiths@nrl.navy.mil

Priority of SLR for POD: Moderate

Other Sources of POD (GPS, Doppler, etc.):

SSN radar and optical

Normal Point Time Span (sec): 5 seconds

Tracking Network Required (Full/NASA/EUROLAS/WPLTN/Mission Specific):

Any available c

SECTION II: TRACKING RESTRICTIONS:

Several types of tracking restrictions have been required during some satellite missions. See *http://ilrs.gsfc.nasa.gov/satellite_missions/restricted.html* for a complete discussion.

1) Elevation restrictions: Certain satellites have a risk of possible damage when ranged near the zenith. Therefore a mission may want to set an elevation (in degrees) above which a station may not range to the satellite.
2) Go/No-go restrictions: There are situations when on-board detectors on certain satellites are vulnerable to damaged by intense laser irradiation. These situations could include safe hold position or maneuvers. A small ASCII file is kept on a computer controlled by the satellite's mission which includes various information and the literal "go" or "nogo" to indicate whether it is safe to range to the spacecraft. Stations access this file by ftp every 5-15 minutes (as specified by the mission) and do not range when the flag file is set to "nogo" or when the internet connection prevents reading the file.
3) Segment restrictions: Certain satellites can allow ranging only during certain parts of the pass as seen from the ground. These missions provide station-dependent files with lists of start and stop times for ranging during each pass.
4) Power limits: There are certain missions for which the laser transmit power must always be restricted to prevent detector damage. This requires setting laser power and beam divergence at the ranging station before and after each pass. While the above restrictions are controlled by software, this restriction is often controlled manually.

Many ILRS stations support some or all of these tracking restrictions. See xxx for the current list. You may wish to work through the ILRS with the stations to test their compliance with your restrictions or to encourage additional stations that are critical to your mission to implement them.

The following information gives the ILRS a better idea of the mission's restrictions. Be aware that once predictions are provided to the stations, there is no guarantee that forgotten restrictions can be immediately enforced.

Can detector(s) or other equipment on the spacecraft be damaged or confused by excessive irradiation, particularly in any one of these wavelengths (532nm, 1064nm, 846nm, or 423nm)?

No.

Are there times when the LRAs will not be accessible from the ground?

No.

(If so, go/nogo or segmentation files might be used to avoid ranging an LRA that is not accessible.)

Is there a need for an altitude tracking restriction? _______ What altitude (degrees)? ________

Is there a need for a go/no-go tracking restriction? _______

For what reason(s)?

Is there a need for a pass segmentation restriction? No

For what reason(s)?

____

____

Is there a need for a laser power restriction? No

Under what circumstances?

____

____

What power level (mW/cm^2)? ____________

Is manual control of transmit power acceptable? ____________

For ILRS stations to range to satellites with restrictions, the mission sponsor must agree to the following statement:
"The mission sponsor agrees not to make any claims against the station or station contractors or subcontractors, or their respective employees for any damage arising from these ranging activities, whether such damage is caused by negligence or otherwise, except in the case of willful misconduct."

Please initial here to express agreement: _____________

Other comments on tracking restrictions:

____

____

____

____

SECTION III: RETROREFLECTOR ARRAY INFORMATION:

A prerequisite for accurate reduction of laser range observations is a complete set of pre-launch parameters that define the characteristics and location of the LRA on the satellite. The set of parameters should include a general description of the array, including references to any ground-tests that may have been carried out, array manufacturer and whether the array type has been used in previous satellite missions. So the following information is requested:

Retroreflector Primary Contact Information:

Name: Ted Finne (or Jake Griffiths)

Address: 4555 Overlook Ave SW

Washington, DC 20375

Phone No.: 202-404-3978 (or 202-404-3508)

Fax No.: 202-767-9388

E-mail Address: ted.finne@nrl.navy.mil (or jake.griffiths@nrl.navy.mil)

Array type (spherical, hexagonal, planar, etc.), to include a diagram or photograph:

Edmunds N-BK7 12.7 mm corner cube reflectors (Silver w/ Inconel and Black Overpaint coating) arranged on a 22.011 inches diameter sphere. [edmundoptics.com/optics/prisms/retroreflection-prisms/n-bk7-corner-cube-retroreflectors/45202]

Array manufacturer:

Naval Research Laboratory (NRL)

Link (URL or reference) to any ground-tests that were carried out on the array:

Ground testing on the array was not performed; the array is similar to ANDE-RR & ANDE-2. However, a different retroreflector arrangement was used on SpinSat for orientation & maneuver research.

The LRA design and/or type of cubes was previously used on the following missions:

Similar arrays were used on ANDE-RR and ANDE-2 missions.

For accurate orbital analysis it is essential that full information is available in order that a model of the 3-dimensional position of the satellite center of mass may be referred to the location in space at which the laser range measurements are made. To achieve this, the 3-D location of the LRA phase center must be specified in a satellite fixed reference frame with respect to the satellite's mass center. In practice this means that the following parameters must be available at mm accuracy or better:

The 3-D location (possibly time-dependent) of the satellite's mass center relative to a satellite-based origin:

The pre-launch measured XYZ center of gravity offsets from the geometric origin (0,0,0) of the sphere are [in mm]: X = +2.49, Y = +5.08, Z = +5.79.

The 3-D location of the phase center of the LRA relative to a satellite-based origin:

The optical phase center offset to the spacecraft origin for each retroreflector is 264 mm. This value was computed using Eq. 6.5.1 in Degnan (1993) for normal incidence to an individual retroreflector. No attempt was made to approximate the response for an ensemble of retroreflectors as viewed from an SLR station.

However, in order to achieve the above if it is not directly specified (the ideal case) by the satellite manufacturer, and as an independent check, the following information must be supplied prior to launch:

The position and orientation of the LRA reference point (LRA mass-center or marker on LRA assembly) relative to a satellite-based origin: The position of the LRA reference to spacecraft origin is not needed. Center of mass information and XYZ positions of corner cube aperture centers are provided.

The position (XYZ) of either the vertex or the center of the front face of each corner cube within the LRA assembly, with respect to the LRA reference point and including information of amount of recession of front faces of cubes:

See Table 1, attached.

The orientation of each cube within the LRA assembly (three angles for each cube):

Each cube is oriented radially outward. The aperture is normal to the tangent of the sphere.

The shape and size of each corner cube, especially the height:

Height: 10.16 (± 0.25) mm + 30-60µm w/ Black Overpaint. Diameter: 12.7 (+0/-0.1) mm + 30-60µm w/ Black Overpaint

The material from which the cubes are manufactured (e.g. quartz):

N-BK7

The refractive index of the cube material, as a function of wavelength λ (micron):

1.51947 for 532 mm; 1.50663 for 1064 mm;

Dihedral angle offset(s) and manufacturing tolerance:

5 arcseconds

Radius of curvature of front surfaces of cubes, if applicable:

The radius of curvature of the aperture of the cubes is infinity. There is no intended power from the aperture.

Flatness of cubes' surfaces (as a fraction of wavelength):

lambda/8

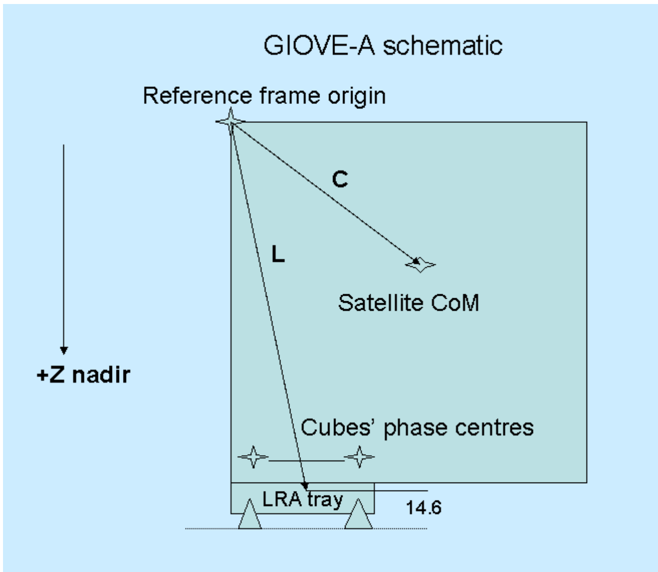
Whether or not the cubes are coated and with what material:

Coated: Silver with Inconel and Black Overpaint.

Other Comments:

SpinSat is fitted with sixty-eight 12.7 mm diameter optical retroreflectors. Sixty corner cubes are located in latitudinal bands at ± 90°, ± 67.5°, ± 45°, ± 22.5°, and 0° with one, six, eight, ten, and ten retros per band, respectively. The last eight are located along a longitudinal band of 0° at: ± 11.25°, ± 33.75°, ± 56.25°, and ± 78.75° latitudes. This is elaborated in Table 1 (attached).

An example of the metric information for the array position that should be supplied is given schematically below for the LRA on the GIOVE-A satellite. Given the positions and characteristics of the cubes within the LRA tray, it is possible to compute the location of the array phase center. Then given the **C** and **L** vectors it is straightforward to calculate the vector from the satellite's center of mass (CoM) in a spacecraft-fixed frame to the LRA phase center. Further analysis to derive the array far-field diffraction patterns will be possible using the information given above.



A good example of a well-specified LRA is that prepared by GFZ for the CHAMP mission in the *paper "The Retro-Reflector for the CHAMP Satellite: Final Design and Realization", which is* available on the ILRS Web site at *http://ilrs.gsfc.nasa.gov/docs/rra_champ.pdf*.

The final and possibly most complex piece of information is a description (for an active satellite) of the satellite's attitude regime as a function of time, which must be supplied in some form by the operating agency. This algorithm will relate the spacecraft reference frame to, for example, an inertial frame such as J2000.

RETROREFLECTOR ARRAY REFERENCES

Two reports, both by David Arnold, are of particular interest in the design and analysis of laser retro-reflector arrays.

- Method of Calculating Retroreflector-array Transfer Functions, David A. Arnold, Smithsonian Astrophysical Observatory Special Report 382, 1979.
- *Retroreflector Array Transfer Functions,* David A. Arnold, ILRS Signal Processing Working Group, 2002. Paper available at *http://ilrs.gsfc.nasa.gov/docs/retro_transfer_functions.pdf*.

SECTION IV: MISSION CONCURRENCE

As an authorized representative of the SpinSat mission, I hereby request and authorize the ILRS to track the satellite described in this document.

Name (print): Andrew Nicholas Date ______________

Signature: ______________________________

Position: Principal Investigator, SpinSat

Send form to:

ILRS Central Bureau
c/o Carey Noll
NASA GSFC
Code 690
Greenbelt, MD 20771
USA
301-614-6542 (Voice)
301-614-6015 (Fax)
Carey.Noll@nasa.gov

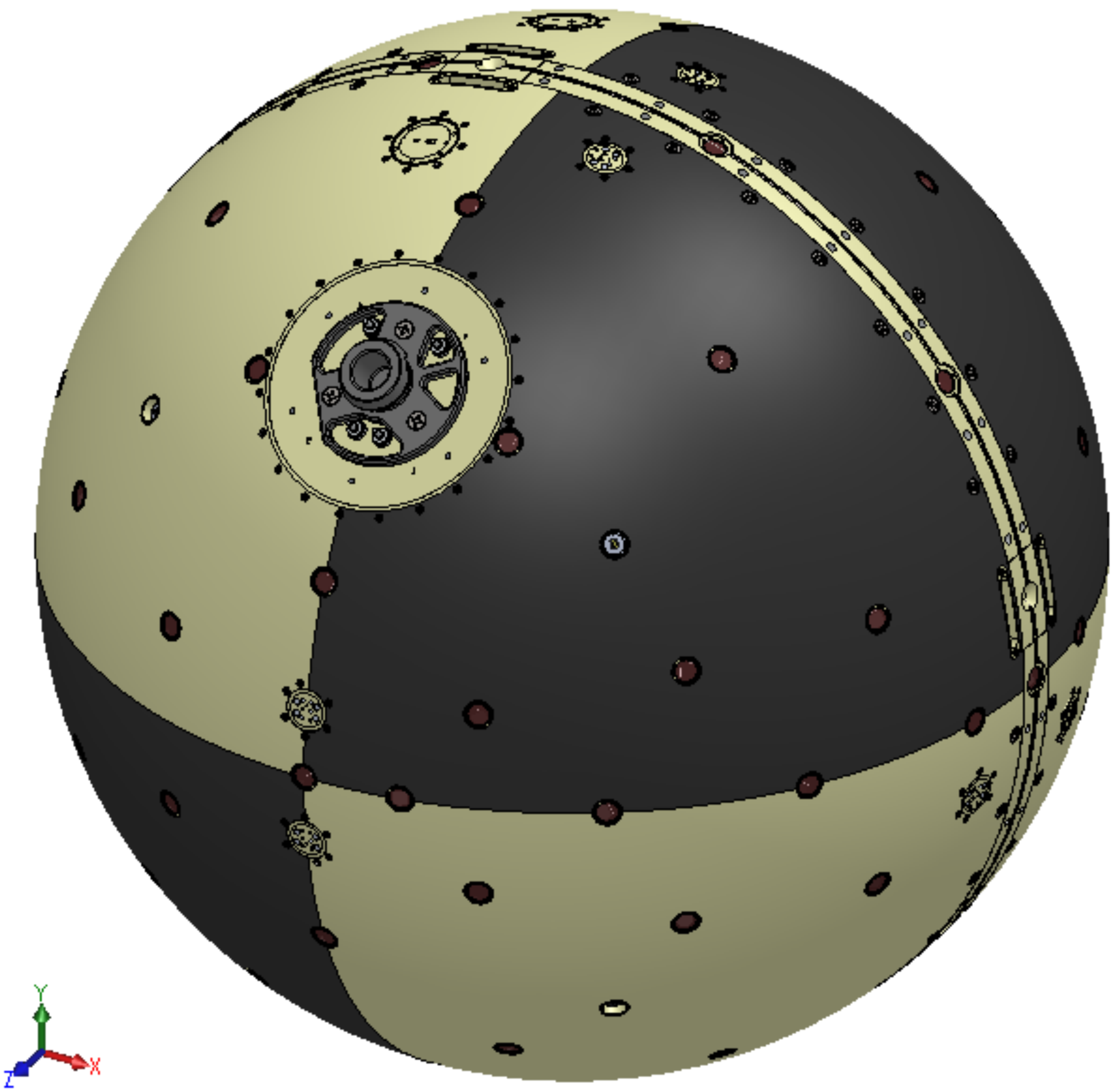


Figure 1. Illustration of SpinSat.

Table 1. Center of aperture X, Y, Z location for each Edmunds BK7 retro on SpinSat.

Lat [deg]	Lon [deg]	rad [mm]	X [mm]	Y [mm]	Z [mm]
0	0	279.54	279.54	0	0
0	36	279.54	226.15	164.31	0
0	72	279.54	86.38	265.86	0
0	108	279.54	-86.38	265.86	0
0	144	279.54	-226.15	164.31	0
0	180	279.54	-279.54	0	0
0	216	279.54	-226.15	-164.31	0
0	252	279.54	-86.38	-265.86	0
0	288	279.54	86.38	-265.86	0
0	324	279.54	226.15	-164.31	0
22.5	18	279.54	245.62	79.81	106.98
22.5	54	279.54	151.8	208.94	106.98
22.5	90	279.54	0	258.26	106.98
22.5	126	279.54	-151.8	208.94	106.98
22.5	162	279.54	-245.62	79.81	106.98
22.5	198	279.54	-245.62	-79.81	106.98
22.5	234	279.54	-151.8	-208.94	106.98
22.5	270	279.54	0	-258.26	106.98
22.5	306	279.54	151.8	-208.94	106.98
22.5	342	279.54	245.62	-79.81	106.98
45	22.5	279.54	182.62	75.64	197.66
45	67.5	279.54	75.64	182.62	197.66
45	112.5	279.54	-75.64	182.62	197.66
45	157.5	279.54	-182.62	75.64	197.66
45	202.5	279.54	-182.62	-75.64	197.66
45	247.5	279.54	-75.64	-182.62	197.66
45	292.5	279.54	75.64	-182.62	197.66
45	337.5	279.54	182.62	-75.64	197.66
67.5	30	279.54	92.64	53.49	258.26
67.5	90	279.54	0	106.98	258.26
67.5	150	279.54	-92.64	53.49	258.26
67.5	210	279.54	-92.64	-53.49	258.26
67.5	270	279.54	0	-106.98	258.26
67.5	330	279.54	92.64	-53.49	258.26
90	0	279.54	0	0	279.54
-22.5	18	279.54	245.62	79.81	-106.98
-22.5	54	279.54	151.8	208.94	-106.98
-22.5	90	279.54	0	258.26	-106.98

(continued on next page)

Lat [deg]	Lon [deg]	rad [mm]	X [mm]	Y [mm]	Z [mm]
-22.5	126	279.54	-151.8	208.94	-106.98
-22.5	162	279.54	-245.62	79.81	-106.98
-22.5	198	279.54	-245.62	-79.81	-106.98
-22.5	234	279.54	-151.8	-208.94	-106.98
-22.5	270	279.54	0	-258.26	-106.98
-22.5	306	279.54	151.8	-208.94	-106.98
-22.5	342	279.54	245.62	-79.81	-106.98
-45	22.5	279.54	182.62	75.64	-197.66
-45	67.5	279.54	75.64	182.62	-197.66
-45	112.5	279.54	-75.64	182.62	-197.66
-45	157.5	279.54	-182.62	75.64	-197.66
-45	202.5	279.54	-182.62	-75.64	-197.66
-45	247.5	279.54	-75.64	-182.62	-197.66
-45	292.5	279.54	75.64	-182.62	-197.66
-45	337.5	279.54	182.62	-75.64	-197.66
-67.5	30	279.54	92.64	53.49	-258.26
-67.5	90	279.54	0	106.98	-258.26
-67.5	150	279.54	-92.64	53.49	-258.26
-67.5	210	279.54	-92.64	-53.49	-258.26
-67.5	270	279.54	0	-106.98	-258.26
-67.5	330	279.54	92.64	-53.49	-258.26
-90	0	279.54	0	0	-279.54
11.25	0	279.54	274.17	0	54.54
33.75	0	279.54	232.43	0	155.3
56.25	0	279.54	155.3	0	232.43
78.75	0	279.54	54.54	0	274.17
-11.25	0	279.54	274.17	0	-54.54
-33.75	0	279.54	232.43	0	-155.3
-56.25	0	279.54	155.3	0	-232.43
-78.75	0	279.54	54.54	0	-274.17